# Briefing Paper

## Science-Based Solutions for the Four Threats to the Health of the Nation's Forests and Grasslands

### Executive Summary

USDA Forest Service

Research and Development

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## Purpose

This briefing paper is a summary of current programs and future directions of FS R&D vis-a-vis the four major threats identified by Chief Dale Bosworth.

This paper is intended: (1) to stimulate discussion among research, land management, and community leadership, and (2) develop an understanding of R&D programs and their main findings about the following:

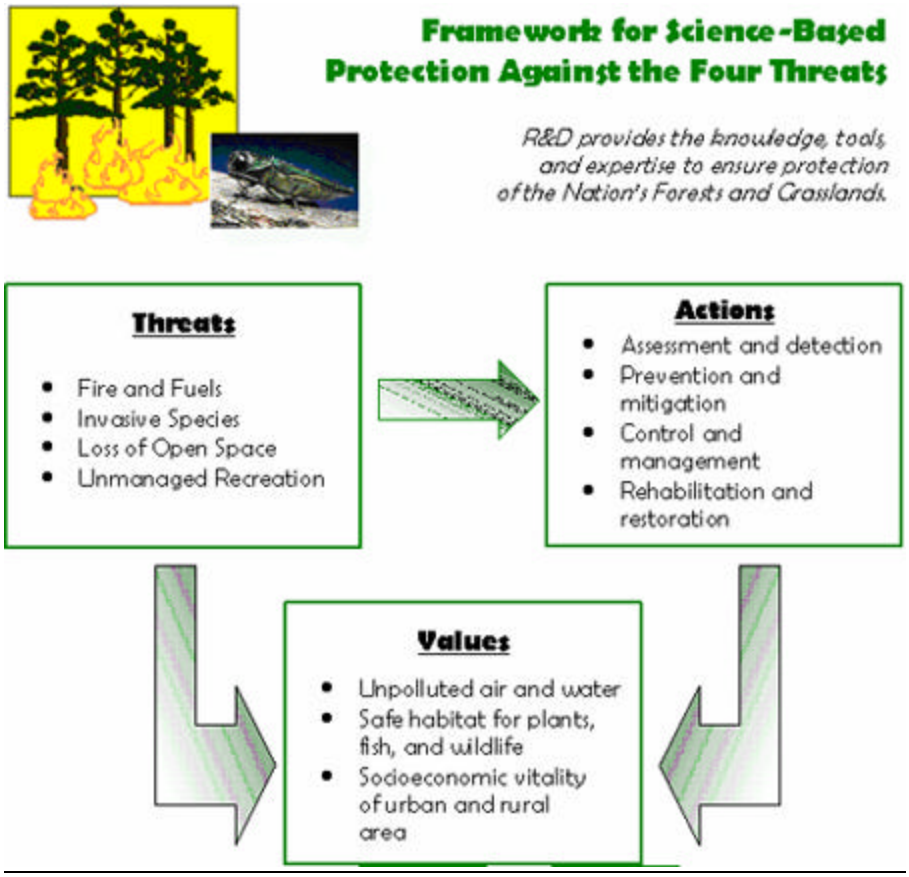
- Enhancing management and community efforts in solving critical problems posed by the four threats.
- Identifying user needs, science gaps, and science application strategies.
- Setting directions in important areas for research.

## Objectives

Forest health management activities are designed to safeguard clean water, clean air, wildlife and fish habitat, energy supply, and the nation's economic and social well-being through the management of natural resources and ecosystems. Major challenges to maintaining these values arise from complex interactions among biophysical and human processes and from threats of catastrophic fire, invasive species, loss of open space, and unmanaged recreation.

R&D's role is to provide the scientific bases for decisions that go into managing to maintain critical values (*figure on the next page depicts these interrelationships*).

The issues of forest health and ecological restoration encompass all aspects of the sciences - ecological and physical well as social and economic disciplines. Research findings are used to minimize the negative impacts of the four threats on ecosystems, communities, infrastructure, and health and safety.




## Knowledge Is Key

With knowledge provided by vigorous research and development efforts, land managers and community leaders can improve their understanding of the underlying causes of the four threats, track and forecast trends, and create integrated solutions to the problems posed by exposure to the four threats. To enhance this understanding, FS R&D is providing: (1) a deeper and broader base of scientific findings, (2) experts to develop solutions, and (3) tools for land managers.

Science helps managers understand how threats are interrelated and how management decisions influence the status of multiple threats and a range of effects on communities and ecological systems. As shown in the figure (*see above*), land managers solve the problems posed by threats to forest and rangeland ecosystems. They must choose and implement courses of action to protect the key values of natural resources. A number of forces can act as threats to forest and rangeland ecosystems thereby reducing their value for clean air, water, habitat, and socioeconomic vitality. Management actions to detect, prevent, control, or recover from threats modify the influence of the threats on ecosystems and reduce potential losses.

Knowledge, tools, and expertise developed by FS R&D is assisting managers by providing them with a broader range of options and a clearer and more

complete picture of the consequences of alternative actions. This knowledge includes greater understanding about individual threats and the values that may be at risk, but also about the interactions among threats and the effectiveness of different management actions. This knowledge is leading to management actions that are more effective, more efficient, and safer for the environment. For example, research is showing that:

- Invasive species flourish in post-fire areas and can be spread by recreationists.
- Increasing parcelization and conversion of forests and rangelands into residential and business areas make fire protection more difficult and costly.
- Unmanaged recreation contributes to the loss of soil and vegetation benefits.

## Expanding Options for Solutions

In the each of the threat areas, research and development provides science-based alternatives in one or more of the following types of management and policy actions:

- Assessment and Detection
- Prevention and Mitigation
- Control and Management
- Rehabilitation and Restoration

New methods of data collection and analysis are enhancing the ability of FS R&D to more rapidly detect and intervene with emerging threats. New understanding about how threats influence ecological, economic, and social processes offer clues about how to prevent them or lessen their impacts. Testing of control methods gives new information about the efficacy and environmental side effects of treatment alternatives and of ways to recover areas affected by a threat or threats.

For more information, visit the FS R&D website at http://www.fs.fed.us, or their individual station websites:

- Forest Products Laboratory: http://www.fpl.fs.fed.us
- International Institute of Tropical Forestry http://www.fs.fed.us/global/iitf
- Northeastern Research Station: **http://www.fs.fed.us/ne**
- North Central Research Station: **http://www.ncrs.fs.fed.us**
- Pacific Northwest Research Station: http://www.fs.fed.us/pnw
- Pacific Southwest Research Station: **http://www.fs.fed.us/psw**
- Rocky Mountain Research Station: **http://www.fs.fed.us/rm**
- Southern Research Station: http://www.fs.usda.gov

# Fire and Fuels

Concerns have been growing for years over declining forest health conditions and increasing incidence of uncharacteristically severe fires. Many forests that are naturally adapted to frequent natural fires and have gone many years without fire, have become overly dense and loaded with fuels. These forests are at abnormally high risk of damages from wildfire as well as insects, diseases, or invasive species infestations.

Under the National Fire Plan, new strategies for fire and fuels management and for restoration and rehabilitation are being developed and implemented on a broad scale. Much of the research that supports and enhances the effectiveness of these activities are funded through the National Fire Plan, the Joint Fire Science Program, and the base science program in Forest Service's R&D budget.

## Current Emphasis

FS R&D is developing science-based knowledge about the basic processes, the effects, and effectiveness of treatments, and the social context of wildland management into tools for analysis and decision support in all phases of fire and fuels management.

### General

- Enhancing our understanding of basic fire behavior, large fires behavior, fire weather, and smoke production and dispersion.
- Developing and applying more accurate fire behavior and weather forecasting models.
- Studying the effect of changing fire regimes, fuel treatments, and post-fire rehabilitation on erosion, water quantity and quality, site productivity and carbon balance.
- Evaluating the public's understanding and acceptance of fire, fire management, and fuel treatments.
- Assisting managers in understanding and addressing the social dimensions of forest values, economics, policy, and utilization of hazardous fuels material.
- Investigating the effects of fire and fuels management treatments and wildfire on key wildlife and aquatic habitat, invasive species, and threatened and endangered species (TES) such as the red-cockaded woodpecker and spotted owl.

- Developing methods for using remote sensing in quantifying, mapping, and monitoring of fuels, fire severity, emissions, and fire behavior.
- Clarifying the effects of climate variability and change on potential fire hazard and fire regimes.

### Assessment/Detection

- Defining, evaluating, and mapping historical natural fire regimes and fire regime condition classes.
- Incorporating forest health and fuel monitoring into the Forest Inventory and Analysis (FIA) system, and evaluating the utility of these data to identify areas with high fuel loads.

### Prevention/Mitigation

- Developing new technologies to produce wood products from small-diameter trees efficiently and economically, conducting economic analyses of the use of materials from fuel reduction and fire-killed timber, and demonstrating how small-scale units can produce electricity and heat from forest biomass.
- Assessing the needs, costs, and potential benefits of prescribed fire and mechanical treatments to reduce fire hazard at the stand and landscape level.

### Control/Management

- Developing and providing training on predictive models and visualization tools for managers to test the consequences of their options or management for fuels management, fire weather, smoke and fire management, ecosystem restoration, and insect and disease control.
- Providing firefighters and fire managers with tools for evaluating fire behavior, predicting emissions, ensuring firefighter safety, and estimating fire effects on active fire incidents.

### Rehabilitation/Restoration

- Developing improved data, models, and web-based modeling tools for estimating the effects of fire and post-fire rehabilitation (BAER) treatments on erosion and runoff.
- Evaluating methods for restoration of fire-dependent forests and rangeland ecosystems.

## What We've Learned

Forest and rangeland systems operate with a vast number of interactions and feedback loops. These systems change and adapt in response to changing environments and to human and natural disturbances. FS R&D is now better able to: (1) articulate the effects of fire exclusion on fuel accumulation and fire regimes in many areas of the West and South, and (2) describe many of the interactions among the following: fire and invasive species, effects of

stand density on vigor, and susceptibility to insect attack and related forest health problems.

Of interests to land managers and fire managers are the following findings and ongoing studies:

- A national coarse-scale analysis of fire regimes and ecosystem conditions estimated that 43 percent of the Nation's Forests is characterized by repeated, low-severity fire regimes. About 75 percent of the forests show either moderate or severe departure from historic fire frequencies and show increased hazard for severe fire.
- Studies of fire history and vegetation recovery have produced models that simulate outcomes of different disturbance patterns and management treatments across broad landscapes.
- New models allow better management of prescribed fires by predicting the effects of treatment alternatives on emissions and regional smoke dispersion.
- Use of small diameter timber and other biomass can partially offset fuel-management costs and provide economic opportunities for communities.
- Changes in the frequency, intensity, duration, and timing of natural disturbances such as fire, drought, insects and diseases, and severe storms are strongly influenced by global climate change and cyclic patterns.
- Experiences of communities affected by fire can help other fire-prone communities to improve preparedness against wildfires.
- Improved predictive capabilities for fire behavior, emissions, and fire effects are helpful in assessing meaningful differences in fire and fuels decisions.

## Further Research

Understanding and predicting complex landscape processes and public response represent a challenge. The Forest Service needs to increase its capacity to delineate the most important interactions and stressors, quantify and understand basic processes, and evaluate site to national-scale impacts of fire and fire management strategies. This will require advanced analytical tools, comprehensive models and model validation, and new methods for communicating research results.

- Develop greater understanding of basic fire physics, nutrient and carbon cycling, and fundamental fire effects.
- Understand the effects of weather and climate change on fuels, fire regimes, and fire management options and how these factors affect carbon storage.

- Improve fire-weather and fire-season forecasts and techniques for predicting extreme fires.
- Identify critical ecosystems that face the loss of fish, plants, and wildlife habitat.
- Identify core information needs and protocols for monitoring systems used in tracking forest health and the effects of management treatments.
- Improve tools for risk assessment, treatment, prioritization, and monitoring at the regional and national scale.
- Develop new uses for fuel material and utilization strategies suited to local conditions and capabilities.
- Develop tools that quickly and efficiently assess the economic feasibility of landscape-scale treatments for reducing fire hazards.
- Use remote sensing efficiently and effectively to supply information to land managers.
- Refine the use of aircraft and satellite remote sensing to fire and fuel management problems.
- Develop landscape-scale fuel management, restoration, rehabilitation, and fuel treatments for the wildland-urban interface (WUI).

# Invasive Species

Invasive species is one of the most significant threats to the environmental and economic values of the nation's forest and rangelands. FS R&D conducts a wide range of critical research to guide management activities, determine the magnitude of problems, and improve intervention efforts.

## Current Emphasis

Broad research in invasive species include: (a) biology of species, (b) environmentally safe control options, (c) risk assessment methods, (d) detection, inventory and monitoring programs, (e) impacts on native species, (f) aquatic and terrestrial ecosystems, and (g) restoration and rehabilitation strategies.

### General

- Defining habits and characteristics of the Asian longhorned beetle, emerald ash borer, Formosan termite, and other invasives.
- Understanding environmental conditions that promote seed germination of invasive plants (e.g., fountain grass in Hawaii).

### Assessment/Detection

- Developing detection techniques for sudden oak death and assessing its potential impacts on forest resources.
- Using aerial and ground surveys to assess insects, disease, and other risks to forests.
- Building risk assessments that help managers: (a) understand interactions between landscape disturbances and management activities (b) minimize risks from invasive plant, and (c) prioritize treatment of existing invasive plants.
- Assessing the impacts of invasive fishes on aquatic systems in California and Alaska and the South. Improving methods to survey populations and predict spatial and temporal movements and impacts of invasives.

### Prevention/Mitigation

- Developing and testing resistant strains of beech, butternut, chestnut, and elm.
- Developing techniques to protect nesting cavities of Puerto Rican parrot and red-cockaded woodpecker from Africanized bees.
- Educating nurseries and landscape professionals about the potential for nursery plants to become invasive.

### Control/Management

- Testing the use of lady beetles from China as a biocontrol for the hemlock woolly adelgid.
- Evaluating the combined use of fire and herbicides to control invasive species on rangelands.
- Developing low-cost, non-toxic treatments for green wood to kill invasive species living in wood imports.
- Studying the impacts of herbicide treatments on native plants and wildlife.
- Understanding the combined effects of fire, fuel treatments, and grazing on invasive plants in dry ponderosa pine forests.

### Rehabilitation/Restoration

- Testing seed germination and survival of native plants for use in rehabilitation and restoration efforts.
- Developing techniques to restore longleaf pine, which has greater resistance to the southern pine beetle than other southern pines.

## What We've Learned

- Invasive nonnative species often reduce the biodiversity of native species and change natural disturbance regimes.
- Invasive tree species can be used to allow the recovery of native tree species on degraded sites in Puerto Rico.
- Outbreaks of the southern pine beetle are associated with ecosystem stressors such as drought.
- A protocol developed for assessing risk of sudden oak death is being used to identify at-risk ecosystems in need of intensive survey and monitoring from other invasive species.
- Establishment of the Nun Moth in the United States would be catastrophic because the moth survives on 11 northeastern conifers and 12 hardwood species.
- In the Pacific Northwest, variable-density thinning compared to even-spaced thinning increased the diversity of native plants in the understory by 50 percent above the original level.
- Nematodes and *Bacillus thuringiensis* kill larvae of the Asian longhorned beetle.
- Post-fire treatments such as erosion control, prescribed burning, other fuels management activities, and grazing can unintentionally encourage the spread of nonnative plant species.

- Northeastern Research Station patented a new strain of Gypchek, a viral pesticide for controlling gypsy moth, which is less labor intensive and less costly to produce than the previous patented version.
- Insects introduced to control the spotted knapweed have become a food source for deer mice and has caused their population to increase.
- Significant reductions in leafy spurge cover and increases in native vegetation can occur when flea beetles that feed on the invasive plant are introduced.

## Further Research

- Study and assess the potential effects of newly introduced invasive species.
- Understand the population biology of invasive and native species interactions and the role of ecosystem disturbance in invasions.
- Understand how large-scale processes such as climate variation, loss of open space, and human uses affect the competitive advantage of invasives.
- Develop and implement technologies for rapid detection, survey, monitoring, and inventory of all species of plants and animals.
- Increase understanding of the long-term consequences of invasive species on the values of forest and rangeland ecosystems.
- Re-establish disease-resistant strains of native species on the impacted landscape.
- Expand work on biological control and other management techniques
- Develop restoration strategies for areas infested with invasive nonnative plants, particularly rangelands and dry ponderosa pine forests.

# Loss of Open Space

Increases and shifts in the population of the United States and changes in the global economy substantially increase the demand for the benefits of healthy, productive forests and rangelands. These same population shifts create changes in the landscape as private farms, ranches, and forestlands break up and give way to urban development. Ecological processes and economic enterprises that depend on continuous forest cover are impacted by this parcelization and fragmentation. Urbanization involves parcelization and loss of contiguous forest cover. Understanding, predicting, and managing the effects of urbanization and land fragmentation improves the ability of the Forest Service to protect forest and rangeland functions, values, and products needed by the American people.

The effects of parcelization affect socio-economic and ecological systems. Fish and wildlife habitats can become fragmented, water and air quality can deteriorate, pests and invasives species can spread, and land is removed from the productive forest resource base. Stream systems can be fragmented by dams, culverts, and other land development activities. Inasmuch as these processes are incremental, their effects may not be noticed until important thresholds have been crossed and resources have disappeared or degrade. Part of the scientific challenge is to understand the processes and thresholds involved in fragmentation, urbanization, parcelization.

## Current Emphasis

### General

- Conducting regional studies (e.g., Oregon Coast Range, Caribbean National Forest/Luquillo Experimental Forest) on the effects of urban development on biodiversity.
- Characterizing the relationship between urbanization and the spread of invasives in the Caribbean islands.
- Developing land-use models to analyze new patterns of urban development.
- Analyzing the effects of demographic trends on forests and management.
- Describing land use tradeoffs (forest products and their prices, wildlife habitat, residential living near forests, and forest recreation).

### Assessment/Detection

- Documenting patterns of fragmentation and urbanization, tracing U.S. residential development patterns as a predictor of forest fragmentation and its effects on forest health and productivity in the North Central Region.

- Predicting trends in population growth near National Forests to help communities prepare for projected growth.
- Documenting the extent of private rangeland owned by ranchers with federal grazing permits, and surveying the social values, attitudes, and beliefs of ranchette owners.
- Measuring and inventorying the urban forest resources and investigating the role of urban forests in supporting wildlife populations and biological diversity.
- Applying an index developed at the Southern Research Station to evaluate the degree and nature of fragmentation.
- Providing FIA data to track broad scale fragmentation.
- Developing new national Landsat-based tree and impervious cover maps (30-m resolution).

### Control/Management

- Developing new technologies and technical information about wood utilization to help forest managers compete economically in the face of urbanization pressures.
- Describing how urbanization affects local forest stands, and assisting city officials in developing appropriate management plans.
- Developing software to help landowners create stewardship plans that qualify for tax abatement and/or state cost-share programs.
- Predicting stream temperatures across entire river basins to help predict the effects of urbanization, management, climate change, and large fires on the fragmentation of aquatic habitats and sensitive, threatened, and endangered species.
- Describing the loss of genetic variation in fish species when habitats are fragmented and using this information to guide conservation standards and goals for managers.
- Providing new hydrologic models to better estimate water flows and guide the design of road crossings passable to fish.

### Rehabilitation/Restoration

- Investigating the effects of urban forests on air and water quality, building energy use, urban climate, ultraviolet radiation, and related factors.

## What We've Learned

Changes in the landscape reduce the contiguity of managed lands as private farm, ranch, and forestlands give way to urban development. The proportion of smaller ownerships among the almost 10 million non-industrial private forest landowners is increasing.

- Change in housing density is the primary driver of forest fragmentation in the North-Central United States as housing density brings other development.
- Changing landscapes from non-urban to urban use can significantly alter carbon levels in soils, thereby influencing concentrations of greenhouse gases.
- Ozone and acid gases can increase with urbanization and fragmentation.
- Habitat fragmentation has made many native species in aquatic ecosystems more vulnerable to extinction and to large disturbances such as fires.
- Fragmentation causes genetic isolation in small mammal populations and prevents expansion in the range of forest carnivores such as fisher.
- As urban sprawl displaces forest use in the Northeastern States, there is a downward trend in the size of forestlands.
- Recreational non-metropolitan communities grew twice as fast as non-metropolitan communities between 1990 and 2000.
- Increasing residential development is associated with decreases in forest stocking and the likelihood that private forest owners will thin stands or plant trees.
- Increasing urbanization in the South likely will be the single most significant threat to sustainability over the next several decades.
- In western Oregon, the proportion of land in low-density and urban developed uses will nearly double by 2055 resulting in more people living near forests.
- Policies for public forestland in the Pacific Northwest have substantial consequences for the forest and agricultural environment in other regions through induced changes in land use, land cover types, and intensity of land management.

## Further Research

- Understand the drivers of urbanization and fragmentation.
- Describe the extent in which patterns of land ownership, such as increased parcelization or mixed ownership, contributes to fragmentation.
- Estimate the impact of loss of open space on forest productivity, resilience, and diversity.
- Identify thresholds of loss of habitat and how this loss affects species with different dispersal capabilities.
- Describe how large-scale disturbances such as fires influence population connectivity and re-colonization.

- Determine the effects of fragmentation on genetic diversity of fish and wildlife populations.
- Integrate econometric land-use models with other models to describe the effects of loss of open space on wildlife.
- Exploit satellite imagery and housing density data to get better information about urban sprawl.
- Link hydrologic models to predict the scale, frequency, and distribution of large, stream-channel disturbances associated with wildfire, large storms, and past management activities.
- Understand better how urbanization introduces forest pests, diseases, and plants.
- Predict better the cumulative effects of different land uses and how they can be modified with land use policies.
- Predict outcomes, restrictions and opportunities of policy alternatives being designed and implemented by local, regional, and state governments.
- Discover cost-effective new means of managing risks of loss to fire, insect and disease in an increasingly urbanized and fragmented environment.
- Develop ways to manage landscapes to maintain a naturally occurring mosaic of habitats and species diversity in fire-prone ecosystems.
- Measure the impact of urban trees on environmental quality, human values and human health.
- Develop options for managing vegetation in environments that are already urbanized.

# Unmanaged Recreation

FS R&D conducts research on unmanaged recreation, including the use of off-highway vehicle (OHVs) in the national forests. Studies focus on three dimensions of unmanaged recreation - resource impacts, recreation supply and demand, and quality of the recreation experience.

## Current Emphasis

### General

- Study elements of quality in visitor experiences and visitor preferences for management action.

### Assessment/Detection

- Investigating the impact of OHV and low-flying aircraft noise on birds and mammals such as goshawk, northern spotted owl, and American marten.
- Characterizing the potential impacts of OHV use on wildlife populations, habitats, and biological diversity in the Sierra Nevada.
- Quantifying air-quality impacts in recreation areas and developing low-cost techniques to monitor air pollution in forests.
- Developing a multiple-species monitoring approach that links data from OHV use and Forest Inventory and Analysis sites on the National Forests.
- Using advanced modeling and remote sensing to provide information on OHV dust and site-specific recreation impacts.
- Conducting a National Survey on 40-year trends in recreation supply and demand.

### Control/Management

- Measuring recreation user conflicts and assessing preferences related to OHV use.
- Evaluating management perceptions of issues and actions related to OHVs.

### Rehabilitation/Restoration

- Developing guidelines for restoring campgrounds and trails and other areas damaged by recreation use in the wilderness and protected areas.

## What We've Learned

- Noise has a negative effect on breeding birds within about 100 meters.
- Disturbance during nesting is more critical than disturbance at other times.
- Noise made by people on the ground disturbs nesting birds more than aircraft noise.
- OHVs emit particulates and ozone precursors.
- Only 7 percent of private lands in the South are available to the public for free recreation, and this is decreasing. The resulting demand on public lands, a relatively scarce resource in the South, will contribute to increasing conflicts between nature-based activities and technology-based activities.
- Many riparian areas in southern California are preferred recreation sites for racially/ethnically diverse visitors. Yet these areas are typically the least developed and the most ecologically sensitive areas.
- People care about specific places and often return to the same areas. Alternative areas may not be acceptable by some user groups whose use may be redirected to minimize impacts.
- Effective techniques are available for recovering trail and campsite damage from unmanaged recreation.

## Further Research

- Study the potential effects of OHVs on regional haze and standards for ambient air quality, soils, and water resources.
- Determine the socioeconomic drivers of recreation use on private lands and the potential for increasing their contribution to the recreation supply.
- Study the national status and trends on interactions between wildlife and recreation, including risks and opportunities and projections of user and population growth.
- Determine the impact of OHV use in sites near bodies of water.
- Study behavioral incentives that could provide recreation experiences sought by visitors with prevention of resource damage.
- Explore options for accommodating both "attachment to place" needs and managing the carrying-capacity of recreation areas.